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RESEARCH PAPER

Expansion of Eucalypt Farm Forestry and Its Determinants in Arsi Negelle District, South Central Ethiopia

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Abstract Declining natural forests and growing demands for wood products are encouraging the rapid expansion of eucalypt farm forestry in Ethiopia, and Arsi Negelle district represents areas with recent plantation expansion in the Rift Valley area of Ethiopia. This study assessed trends in eucalypt planting over the last five decades, identified the determinants, and examined perceptions of local stakeholders towards this expansion in the district. Quantitative data were gathered through a household survey and farm level inventory. About 90% of the respondents had planted eucalypts, and 52% of them were engaged in planting since the late 1990s. About 11% converted cropland to eucalypt woodlots, which is also a growing trend in the area. Proximity to Arsi-Forest Enterprise ($P < 0.01$) and area of land holding ($P < 0.01$) positively and significantly affected both decision to plant and land area allocated to eucalypts plantings. Active labour in the family negatively and significantly ($P < 0.05$) affected planting decisions, while education level of the household head positively and significantly ($P < 0.05$) affected land area allocated to eucalypts plantings. Despite strong policy discouragement and perceived adverse ecological effects by the farmers themselves, 96% of them and 90% of the district experts support the expansion. Eucalyptus has become the most desired and planted tree genus, and economics not ecology appears to drive its expansion. Unless better alternative sources of cash income and substitutes for energy and construction materials are found, its expansion is likely to continue even at the expense of

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cropland. It is concluded that research is needed to fine-tune current eucalypt farm forestry practices to reduce the associated ecological externalities, rather than grossly banning eucalypt planting by smallholders.

Keywords Area under eucalypts · Farm income · Perceptions on eucalypt · Proximity to forest · Proximity to market · Wealth status

Introduction

In Ethiopia natural forests and woodlands are shrinking while population and wood demands are rapidly increasing. The common response to this problem has been establishment of plantations of fast-growing tree species (Lemenih and Bongers 2010). From the second half of the nineteenth century, successive governments in Ethiopia have attempted, to varying degrees, to promote plantations to compensate for the declining supply from the natural forests (Pukkala and Pohjonen 1990; Bewket 2003; Mekonnen et al. 2007). However, reforestation and afforestation in the country is very slow compared to deforestation (Bekele 2003; Achalu 2004; Lemenih et al. 2008). Furthermore, most of the past reforestation efforts were driven by the State, NGOs and aid agencies, and most of these agents retreated from promoting plantations after the mid-1980s. Instability of rural institutions and forest related policy constraints was not encouraging to tree plantings outside homestead plots (Kassa et al. 2011). However, smallholder farmers are nowadays taking the lead in expanding tree planting in the form of farm forestry (Turnbull 1999; Jagger and Pender 2000, 2003; Bewket 2002, 2003; Achalu 2004; Abebe 2005; Mekonnen et al. 2007; Duguma and Hager 2010).

Eucalyptus is the Ethiopian farmers' preferred genus, due to its rapid growth, coppicing ability, ease of management and unpalatability to animals in a situation of free grazing common in the countryside. It is also a resilient species that performs better than most indigenous species in a degraded environment with water shortages and low soil fertility (Jagger and Pender 2003). In addition, the sale of eucalypt poles and products has the potential to raise farm income, reduce poverty, increase food security and diversify smallholder farming systems in less-favored areas (Bewket 2003; Jagger and Pender 2003; Mekonnen et al. 2007; Kebebew 2010). The genus is thus expanding from State-driven forest developments to community and household woodlots (Turnbull 1999; Jagger and Pender 2000; Mekonnen 2000; Bewket 2003; Mekonnen et al. 2007; Lemenih 2010; Lemenih and Bongers 2010, 2011).

The expansion of eucalypts plantations has become a highly polemical debate between environmentalists, foresters and policy-makers. Foresters maintain eucalypts and other fast-growing exotics can help meet increasing wood demands of local communities and industries alike, and contribute to household cash income as well as reducing logging pressure on the dwindling natural forests (Bewket 2003; Mekonnen et al. 2007; Lemenih 2010). In some cases eucalypts also help in facilitating the restoration of biologically rich natural forests (Yirdaw 2002; Lemenih and Teketay 2005; Lemenih and Bongers 2010). However, environmentalists are opposed to

eucalypts due to the perceived ecological hazards. Policy-makers also appear to side with the environmentalists (e.g. Jagger and Pender 2003; Kebebew 2010). For instance, until the end of the 1990s, the main tree seedlings produced in government nurseries were of eucalypts. But these have been totally abandoned starting from the early 2000s (Mekonnen 2010). Similarly, in 1997 the Regional Government of Tigray, one of the regional states in Ethiopia, imposed a ban on eucalypt tree planting on or near farmland (Jagger and Pender 2000), which was repeated in Oromia Regional State in 2002 (Kebebew 2010). The ban was precipitated by concerns about the potential negative environmental externalities associated with eucalypts, and the desire to reserve farmland for crop production (Jagger and Pender 2000, 2003; Kebebew 2010).

Despite the conflicting views, farmers continue to expand eucalypt plantings in Ethiopia (Mekonnen et al. 2007). In fact, in addition to institutional issues several factors affect farmers' tree planting decisions and areas they allocate to trees. Some of these factors include household socio-economic characteristic, access to forest products, extension supports, road access and market factors (Mekonnen 1998; Nibbering 1999; Salam et al. 2000; Amacher et al. 2004; Hansen et al. 2005). Mekonnen (1998) showed that households with relatively more male labor, relatively higher income and a higher proportion of off-farm income are more likely to plant trees. Gebreegziabher et al. (2010) found that land size, age, gender, tenure security, education, exogenous income, and agro-ecology increased both the propensity to plant trees and the amount of tree planting, while increased livestock holding affected both decisions negatively. Salam et al. (2000) from a study in Bangladesh reported that economic factors play a larger role than ecological factors in determining farmers' decisions to plant trees, in contrast to the findings of Emtage and Suh (2004) from Philippines where tree-planting and management intentions are primarily driven by household needs for timber and construction materials. Dewees (1995) similarly noted that household fuelwood demand and market prices for fuelwood are most important determinants in influencing farmers' decisions to plant trees in Malawi. Some studies in Ethiopia also show that farm revenue could be could be increased by tree cultivation. Based on cost-benefit analysis of woodlots in Tigray Region, Jagger and Pender (2000) concluded that planting eucalypt trees yields high rates of return compared to crop farming, well above 20% under most circumstances. According to Holden et al. (2003), household income could have been increased by up to 30% if farmers in Andit Tid district of central Ethiopia planted trees on 20% of their land unsuitable for crop production. Mekonnen et al. (2007) found that planting of eucalypts by poor households contributed about 28% of household's income and provided more than 90% of the wood required for household consumption in the central highlands of Ethiopia.

According to (Bewket 2003), few studies can be found which focus on the causes of expansion of eucalypt plantation by smallholders in Ethiopia. This suggests a need for additional studies to increase understanding of the factors that farmers consider in making decisions about planting eucalypts and size of land area allocated to them. The objectives of this study were to examine the trend over time of eucalypt tree planting by farm households in Arsi Negelle district of central Ethiopia, identify determinants of household decisions to plant and areas allocated

to eucalypts, and assess the perceptions of farmers and other stakeholders in the district on eucalypt plantation expansion. The hypothesis was that several household characteristics such as family size, active labour size in the household, area of land holding, the age, gender and education level of the household head, proximity to road and market and proximity to forest affect decision to plant and area allocated to eucalypt.

History of Eucalypts in Ethiopia

Eucalyptus is a diverse genus of flowering trees (and a few shrubs) in the Myrtaceae family. It is a genus with more than 700 species, mostly native to Australia, with a few species native to New Guinea and Indonesia and one (*Eucalyptus deglupta* or bagras) to the Philippines. Nowadays, several eucalypt species are cultivated particularly throughout the tropics and subtropics including the Americas, Europe, Africa, the Mediterranean Basin, the Middle East, China and the Indian Subcontinent. According to FAO (2006), *Eucalyptus* is the third largest genera used in plantation forestry globally.

In Africa, eucalypt plantations are found widely in Ethiopia, South Africa, Kenya, Zimbabwe and Tanzania (Dessie and Erkossa 2011). Eucalypts were introduced to Ethiopia in about mid-1890s, under the rule of Emperor Menelik II either by the French advisor Mondon-Vidailhet or by the Englishman Captain O'Brian (Getahun 1999, 2002). Menelik II endorsed its introduction and planting around the then newly establishing capital city (Addis Ababa) to combat massive deforestation that led to a shortage of wood for construction and fuel. Due to the slow growth rate of indigenous tree species such as *Juniperus procera, Olea europaea* and *Podocarpus falcatus,* eucalypts were successful, and plantations spread quickly from the capital. In the mid-1940s David Buxton writing on central Ethiopia, stated that eucalypt trees had become an integral and pleasing element in the central highland landscape and had largely displaced the slow-growing native *Juniperus procera* species (Buxton 1957).

Eucalypts are known by various local names, e.g. *Bahir Zaf* in Amharic and *Bar Gammo* in Oromiffa, which mean a tree from across the ocean (an introduced species). During the first introduction about 15 species were acquired, including *E. camaldulensis, E. globulus, E. tereticornis, E. amygdalina, E. largiflorens, E. cladocalyx, E. cornuta, E. diversicolor, E. incrassata, E. leucoxylon, E. melliodora, E. patens, E. resinifera, E. rudis* and *E. Salubris*. These were imported directly from Australia. Nowadays, about 60 eucalypt species are found in Ethiopia (Teketay 2000; Gil et al. 2010), and they are the most widely grown plantation species in the country. Eucalypts account for about 58% of the total planted area in state-owned plantations (Teklu 2003) and almost 100% of farm forestry (WBISPP 2004; Lemenih 2010; Lemenih and Woldemariam 2010). The most widely grown species in Ethiopia are *E. camaldulensis*, *E. globulus*, *E. grandis* and *E. saligna*.

Nowadays, it is common to see at least a few eucalypt trees in homesteads of rural, periurban areas and townships across the highlands of Ethiopia (Turnbull 1999; Bewket 2003; Lemenih 2010). Eucalypt species have become the dominant

source of wood, contributing most of wood consumed in construction and energy across the country (Mekonnen et al. 2007; Lemenih 2010). As a result, eucalypts make a substantial contribution in slowing down the pressure of deforestation and degradation of natural forests and woodlands (Mekonnen et al. 2007; Lemenih and Bongers 2010), and play a considerable role in reducing rural poverty and enhancing food security (Lemenih 2010).

Over the last two decades eucalypt woodlots have expanded at an extraordinary rate across the highlands of Ethiopia (Teklay 1996; Turnbull 1999; Asnake 2002; Mesfin 2002; Negash 2002; Ewnetu 2008; and Lemenih 2010). For instance, out of the 92,000 ha of land covered with eucalypt plantations in Amhara Regional State of Ethiopia, about 67% is farm forestry developed by smallholder farmers in the last two decades (Lemenih 2010). Wood scarcity to meet own demands, declining farm productivity, need for increased sense of land security, and better adaptive capacity of the species on degraded plots are often mentioned as major factors inspiring farmers' to convert farm plots to eucalypt woodlots (Jagger and Pender 2000; Achalu 2004; Mekonnen et al. 2007). Among some communities in Ethiopia, planting eucalypts gives a household an additional social status (Achalu 2004), besides helping meet household wood and cash requirements. However, all farmers are not planting and among those planting the area allocated to eucalypts also vary depending on several factors such as socioeconomic status (farm and livestock holding, agricultural income, labour availability), market access, and gender and education level of the household head are expected to influence to decision to plant and the area allocated to eucalypts. This study examined the contribution of these explanatory variables in farmers' decisions.

The Study Area

The study area is the Arsi Negelle woreda (district), located between 7°20′–7°25′N and 38°45′–38°50′E (Fig. 1). The district covers three major climatic zones based on altitude (low, mid- and high-altitude), ranging from 1,500 to 2,300 m a.s.l. The high-altitude zone occupies the largest area. Mean annual temperature in the district varies between 25°C in the low altitude areas to 18°C in the higher altitude areas. Mean annual rainfall also ranges from 500 mm in the low altitude areas to 1,000 mm in the high altitude areas. The district has a total population of 147,114, of which 82% live in rural areas. About 30% of the total land surface of the district is covered with crops, particularly maize and wheat, and annual crops account for 95% of all cropland. Farmers maintain and plant various tree species both indigenous and exotic on their landholdings. The indigenous species maintained on farmlands are similar to those species that compose the original vegetation and include *Podocarpus falcatus, Cordia africana, Croton macrostachyus, Ficus* species, *Albizia gummifera* and *Prunus africana*. These species are seen sparsely distributed on farmland, grazing areas and around water bodies. The major exotic species planted by farmers are *Eucalyptus camaldulensis, Cupressus lusitanica, Eucalyptus saligna* and *Grevillea robusta.*

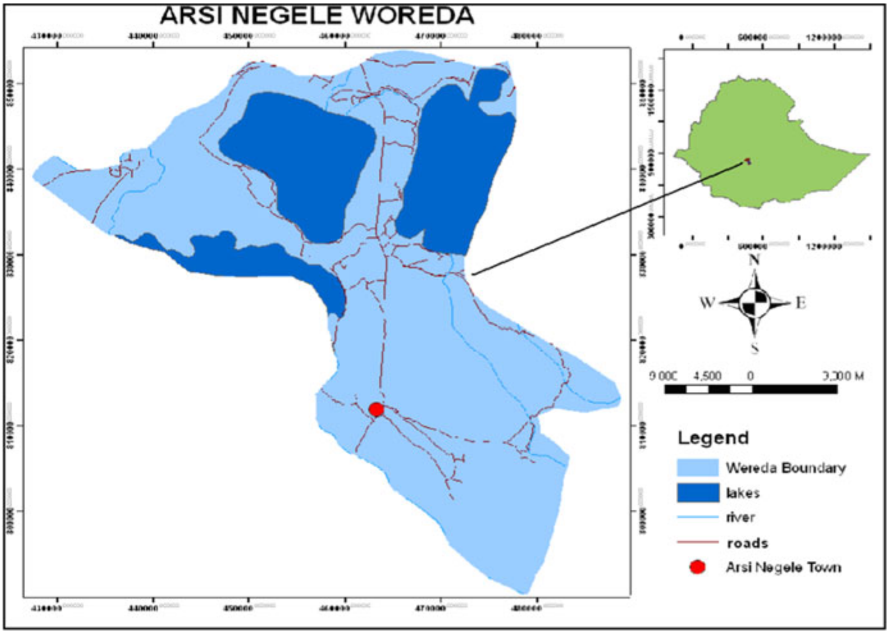

Fig. 1 Arsi Negele District which is the study area and its location within Ethiopia (the *green map* in the figure)

Research Method

Formal and informal socio-economic surveys and farm tree inventories were conducted. An area about 18 km long lying between Arsi Negelle town in the west and Munessa natural forest managed by Arsi Forest Enterprise (AFE) in the east was selected for the study (Fig. 2). The site was then divided into five blocks of 3.5 km length. Each block was represented by a transect line running in a north to south compass direction. The first transect (designated Transect 1) was the closest to the town of Arsi Negelle while the last transect (Transect 5) was close to the natural forest managed by AFE. These defined the proximity to market and forest variables, respectively. Along each transect, six villages—three to the right and three to the left of the main road passing through the sample area—were selected. Villages were selected such that the first was the nearest village to the road, the second about 2 km from the road, and the third about 5 km from the road. All three villages on both sides of the road fall more or less on a straight transect line defined by compass. Accordingly, a total of 30 villages were included in the study.

After obtaining the names of all household heads in each village, and identifying their wealth status (rich, medium or poor)[1] with the help of two or three key

[1] The wealth categorization as rich, medium and poor in this study shows the relative position of a household in terms of possession of area of farm land, house type and number of livestock, criteria used in the area to define wealth status. However, it does not imply that 'a rich' household is 'wealthy' in the global context of wealth definition.

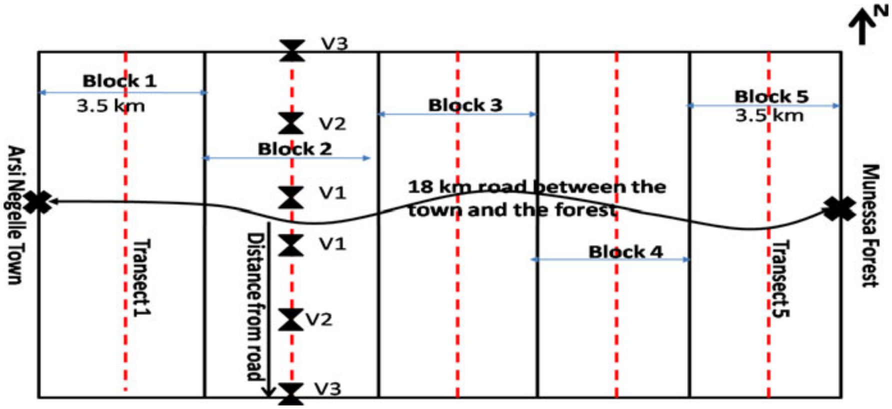

Fig. 2 Layout of the study design and sampling frame (*V1*, *V2*, *V3* refers to villages selected left and right of the road)

informants in each village, six household heads were randomly selected from each village, two per wealth category. Thus, a total of 180 respondents (i.e. 60 per wealth category, 36 per transect, and 6 per village) were selected for the survey. Criteria for wealth ranking considered by the key informants were land size, number of livestock held and the type of house owned (whether covered with corrugated iron sheet or grass thatched). These criteria were selected by—and agreed upon among—the key informants. Wealth ranking was done in such a way that the researcher read the name of the household head from the inhabitant record list, and each of the key informants turn by turn and individually assigned a wealth rank to the particular household. The results of each were compared, and in most cases the assignment was unanimous. In other cases, the category assigned by two key informants was accepted. The weighted mean was used to determine the category in the few cases when the three key informants all differed in their ranking.

A structured questionnaire that focused on household demographic and socio-economic characteristics, area of landholding, participation in eucalypt planting (when, how much and why), and on perceptions about eucalypt plantations and their expansion was prepared, tested, and translated into the local language Oromiffa. Personal interviews were conducted with the 180 household heads. Also, a total of 30 experts in the district were interviewed. In addition, farmlands of 90 farmers (30 from each wealth category, three from each village) were randomly selected and inventories were made of eucalypt tree holdings. The inventory collected data on number of eucalypt trees owned by the households and degree of stocking of eucalypts trees.

Data Analyses

The qualitative data was analyzed on the spot and presented back to villagers in the form of summaries of findings to verify. The quantitative data were analyzed using descriptive and inferential statistics. Frequencies and means were calculated to

describe key variables. Chi-square tests, ANOVA and regression analyses were used to examine relationships between key variables. ANOVA was used to test for significance differences due to wealth status in the allocation of land to eucalypt plantations, and if the number of trees planted varied with proximity to roads and markets and to forests. A binary logistic regression (binary logit) model was employed to examine the relationship between socio-economic variables and farmers decisions to plant trees, while a multiple linear regression (tobit) model was used to identify factors that influence farmers' decisions to allocate land area for eucalypts planting. MINITAB version 13 (for ANOVA), Statistical Package for Social Sciences (SPSS) version 13 (for binary logit model) and Limdep NLOGIT 3.0 (for tobit model) were used to analyze the quantitative data.

The Binary Logit Model

This model was used to examine factors that influence farmers' decisions to plant eucalypts. The dependent variable is binary: planter or non-planter of eucalypts. A planter is defined as a household that has planted at least one eucalypt tree on their plots regardless of the form of planting ($Y = 1$ for planting and $Y = 0$ for no planting). The independent variables considered were proximity to road (distance in km from the main road), proximity to the forest (distance in km from Munessa Forest), respondent's age, educational level (school grade attained), total family size, active labour in the family (number of family members in the age category of 18–65 years of age), and area of landholding. When zero is assigned for a household which has not planted eucalypts and one for a household which has planted, the logistic distribution function is specified as follows:

$$P_i = E(Y = 1|X_i) = \left(\frac{1}{1 + \exp[-(\beta 0 + \beta 1X1i + \beta 2X2i + \cdots + \beta kXki)]}\right)$$
$$= \left(\frac{1}{1 + \exp(-zi)}\right)$$

where

$$Z_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta k X_{ki}$$

The probability that a household plants eucalypt, $P_{i,}$ is given by

$$P_i = \left(\frac{1}{1 + \exp(-zi)}\right)$$

and the probability that a household does not plant $(1-P_i)$, is expressed as

$$(1 - P_i) = \left(\frac{1}{1 + \exp(-zi)}\right)$$

$P_i/(1-P_i)$ represents the odds ratio in favour of being a household which planted eucalypts.Taking the natural logarithm of the equation of the odds ratio, the logit model Li is

$$\mathrm{Li} = \mathrm{Logit}\ (pi) = \ln\left(\frac{Pi}{1 - Pi}\right) = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \cdots + \beta k X_{k,i}$$

where X_1, X_2,… are the explanatory variables, K designates the number of the explanatory variable (the regressors), and i represents a sample household head who is specified as either a planter ($Y = 1$) or non planter ($Y = 0$).

Multiple Linear Regressions Model (Tobit)

This model was used to identify factors that influence the area of land allocated to eucalypts. The independent variables were the same as for the binary logit model. The dependent variable is continuous, and households included in the analysis are limited to those which planted eucalypts. The model used was specified as

$$Y = a + \sum_{i=1}^{n} biXi + e$$

where, $Y =$ area planted allocated to eucalypts (ha), $a =$ constant or intercept, $bi =$ regression coefficients, $X_i =$ explanatory variables (X_1 to X_6), $e =$ the stochastic disturbance.

Results

Household Characteristics

Family size ranged between 1 and 26 persons, with an average of 9 persons, which is much higher than the national average of six. The young population, of 17 or less years old, accounted for 58% of the total. The age of the respondent household heads varied between 20 and 71 years, with an average was 42 years. Most respondents (72.2%) can read and write. The average area of landholding per household was 1.45, with the range of 0.25–5 ha. The major economic activities of the study area are crop cultivation, animal husbandry, tree farming and petty trade. Tree planting is an emerging economic activity with growing importance in the study area.

Land Allocation for Tree Planting

Area of land allocated for the three land uses: annual crop, tree planting and grazing varied significantly ($P < 0.001$) between households in the three wealth categories. The area allocated for the three land uses increased significantly with wealth category (Table 1). The rich households allocate significantly higher areas of land to the three land uses compared to the poor households, and also significantly higher areas of land to tree planting and grazing compared to the medium households (Table 1).

Table 1 Average land area (and SE) in ha allocated to annual crops, trees and grazing by households in the three wealth categories in Arsi-Negelle District ($n = 180$)

Land use	Wealth category			P value
	Poor	Medium	Rich	
Cropland	0.79 (0.437)[a]	1.08 (0.469)[b]	1.54 (0.868)[b]	.000
Tree planting	0.03 (.039)[a]	0.05 (0.055)[a]	0.18 (0.248)[b]	.000
Grazing land	0.27 (.188)[a]	0.29 (0.149)[a]	0.42 (0.035)[b]	.001

Different letters along the rows show significantly different area of land allocated for the different uses

Trends in Eucalypt Planting

Eucalyptus is the most commonly planted tree genera in the study area. About 88% of the respondents planted eucalypts trees When respondents were asked to identify the most important reason for preferring this species, 49.4% identified the inherent characteristics of the genus (in terms of adaptability, fast growth and non-palatability for livestock) as the most important criterion while 43% identified increased income from sale of eucalypt wood as their most important reason for preferring this species.

In general, eucalypt planting is expanding in the study area. Only one of the respondents was found to begin planting eucalypt in the late 1960s, the majority (52%) having begun planting eucalypts from 1998 (Table 2). The interviewed key informants also confirmed that the introduction and expansion of eucalypts in the area is relatively recent as compared to the introduction of the genera to the country over a century ago.

Among the households which have planted eucalypt in 2007–2008 planting season, 11.1% converted part of their crop fields. Among those who converted their crop fields to plantations, 85% were rich farmers while households from the poor and medium wealth categories accounted for 10 and 5% of the converters, respectively. The two major drivers of conversion, as reported by all of the respondents who converted crop fields, were higher income from eucalypts than from annual crops, and reduced crop yields from decline in soil fertility.

Planting Practice and Sources of Seedlings

In the study area farmers begin preparing planting sites at least 3 months before planting, with preparation beginning in May and ending at planting in July. Site is prepared using ox-ploughs, and when areas are small they are prepared using hand hoes. Almost all interviewed farmers adopt a closer spacing than that recommended

Table 2 The number of farmers who began planting eucalypts at different periods in the past four decades

Period	Before 1968	1969–1978	1979–1988	1989–1998	1999–2008
No. of respondents	1	6	16	46	94

by extension agents. Wider spacing is practiced in state industrial plantations where 1.5 m × 1.5 m to 2.5 m × 2.5 m spacing is used depending on plantation objectives. Inventory of the plantations revealed that the spacing used by farmers ranged between 0.25 m × 0.25 m and 0.7 m × 0.7 m. Hence, the stocking rate of eucalyptus on farmers' plots ranges between 15,000 and 40,000 stems/ha. Planting is mostly as woodlots and in few cases as strips. Most (74.8%) of the farmers practice establishment as woodlots by dividing their land into smaller units, each unit being planted in different years, to allow a continuous annual harvest. The rest of the farmers preferred to plant the entire area at once. Most (64.3%) of the farmers preferred potted seedlings, because of their high survival rate and faster growth, while the rest used bare-rooted seedlings because of their ease of transport.

Sources of eucalypt seedlings are mainly own nursery, government nursery and market place, but with some from neighbours, NGOs and forest enterprises. About 63.8% grew their own seedlings, 14% receive seedlings from government nurseries, 10.5% purchase it from market places and the rest from other sources such as gifts from neighbours or NGOs.

Determinants of Eucalypt Planting

Proximity to the Munessa forest managed by AFE ($P < 0.01$) and area of landholding ($P < 0.05$) positively and significantly affected farmers' decision to plant eucalypts. However, proximity to road, respondent's age, education level of household head and total family size had no significant effect (Table 3).

As indicated in Table 4, the tobit analysis revealed that proximity of households to Munessa forest ($P < 0.001$), educational level of the household head ($P < 0.01$) and landholding ($P < 0.01$) positively and significantly affected the area of land allocated by a household to eucalypt plantation. The relationship between area allocated to eucalypts and distance from road, respondent's age and total family size were positive but not statistically significant. Active labour in the family had a negative but non- significant effect on land allocation for eucalypt by the farmers in the study area.

Table 3 Socio-economic and physical factors affecting farmers decision making to plant eucalypts in Arsi Negelle District ($N = 180$)

Factor	B	SE	Wald	df	Sig	Exp(B)
Proximity to road	−0.038	0.334	0.013	1	0.909	0.962
Proximity to forest	0.566	0.218	6.752	1	0.009**	1.761
Respondent age	−0.021	0.026	.667	1	0.414	0.979
Education level	−0.047	0.296	.025	1	0.874	0.954
Family size 1 (active labour)	−0.465	0.182	6.569	1	0.010*	0.628
Family size 2 (total family)	−0.082	0.070	1.364	1	0.243	0.921
Area of landholding	0.798	0.374	4.569	1	0.033*	2.222
Constant	−2.047	1.765	1.344	1	0.246	0.129

$\chi^2 = 22.40$; Significance 0.002; $r^2 = 91.70$; Significance level: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 4 Tobit model outputs on determinant factors influencing area of land allocated to eucalypt by farmers in Arsi Negelle District ($N = 180$)

Variable	Coefficient	Standard error	b/EE	P value
Constant	−.31261	0.07010	−4.459	0.0000
Proximity to road	0.014373	0.00178	1.166	0.2070
Proximity to forest	0.03214	0.00933	3.445	0.0006***
Respondent age	0.00158	0.00109	1.451	0.1468
Education level	0.04239	0.01405	3.018	0.0025**
Family size 1 (active labour)	−0.00226	0.00526	−0.430	0.6670
Family size 2 (total)	0.00493	0.00294	1.673	0.0943
Land holding	0.06261	0.01906	3.285	0.0010***

Significance level * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Proximity to road did not significantly affect area of land planted with eucalypts. Wealth status of the households on the other hand significantly ($P < 0.05$) affected land area allocated to eucalypt plantations in all transects except transect V, the one closest to the forest. The area allocated to eucalypt planting was significantly different between the poor categories of the different transects ($P < 0.05$) (Table 5).

Views on Eucalypt Plantation and Expansion

About 95% of farmer respondents confirmed that eucalypt planting was increasing in their villages, while 5% perceived that the area has either remained the same or declined. Similarly, 96.7% of the interviewed experts of the district perceived that eucalypts planting is expanding. Rising demand for wood, desire for income from selling poles, increasing distance from the forests and woodlands to access wood products for subsistence, and increasing frequency of drought that affects crop and livestock production were identified as major reasons driving the expansion of eucalypt plantations.

Table 5 Summary results of one-way ANOVA for mean land allocation for eucalypt plantations (ha) by proximity to forest and wealth category in Arsi-Negelle District ($N = 180$)

Transect[a]	Wealth status			P value
	Rich	Medium	Poor	
1	0.0667	0.01988	0.01497	0.011
2	0.093	0.04945	0.01383	0.005
3	0.2212	0.06100	0.01710	0.016
4	0.2456	0.06380	0.05100	0.047
5	0.163	0.04510	0.00920	0.063
P value	0.300	0.21400	0.01100	

[a] Transect V is closest to natural forest and transect I is closest to town of Arsi Negelle (market)

Nearly 57.8% of the respondent farmers perceived that expansion of eucalypt plantations will create problems in the future. Among these respondents, 51% identified lower crop yields from eucalypt competition as their major concern, 22.1% reported less undergrowth, 6.7% lowering of ground water level and 5.7% soil degradation as the major reason. Other reasons identified included reduction in food availability at household level if most land is occupied by plantations. Similarly 90% of the district experts supported the expansion of Eucalypts plantations. The reason why the experts support the expansion is because it helps farmers to increase their income and to balance the increasing gap between demand for wood products and the supply.

Despite the perceived negative ecological impacts of eucalypts plantings among the respondent farmers, the majority (96%) of the respondents still support the continued expansion of eucalypts plantations. Among the respondents that support the expansion, 92.2% of them plan to continue planting eucalyptus in the future while 7.8% of the supporters have no plan to do the expansion themselves because it would compete with grain production of their households. About 90% of the interviewed experts also supported the expansion of eucalypt plantations because they believed that this helps farmers to substantially increase their income and also meet own and market demand for wood products.

Discussion

Despite its recent introduction to Arsi-Negele as compared to its introduction to Ethiopia, plantations of eucalypts are rapidly expanding. This expansion is taking place despite strong criticisms on the genus and good awareness among the farmers of its negative ecological effects. Farmers' decision to plant and the area they allocate to eucalypts plantations are affected by several household socio-economic and physical factors. Number of active labour in a household affected negatively the decision of farmers to plant eucalypt. This may be because as children (especially males) grow to adulthood, it is often the responsibility of the parents to share their piece of land and help them to begin independent life. This further shrinks the land holdings of a household, creates stress on families and affects their land use decisions on their remaining parcels, for tree planting, annual crop production or grazing. This finding, on the other hand, contradicts several other studies where family size was found to have no significant effect on size of land allocated to eucalypt plantings (e.g. Gebreegziabher et al. 2010) or have a significant and positive influence on plantings (e.g. Holden et al. 2003; Duguma and Hager 2010). However, these studies did not disaggregate total family size into dependents and active labor.

Area of landholding is positively correlated with farmers' decision to plant eucalypts. This is in agreement with results from several studies (e.g. Ball 1995; Teshome 2004; Getahun 1999; Asnake 2002; Kebebew 2002; Bewket 2003). Moreover, the study revealed that area of eucalypt planting increases as one moves closer to the natural forest managed by government agency, indicating the demonstrative effects or exposure of the households to forestry practices, and improved access to seedlings and technical assistance that can result in increasing

tree farming and the benefits from the business. This is in agreement with the study by Nibbering (1999) in Sewu hills in Java, Indonesia that reported that a government-launched tree-planting campaign and demonstration contributed to the establishment of a critical mass of farmers who adopt tree growing. However, this finding contradicts results from several other studies (e.g. those of Bewket 2003; Mekonnen et al. 2007; and Duguma and Hager 2010) of increasing tree planting practices with increasing distances from the state forest. These contrasting results imply that tree planting is not necessarily encouraged by scarcity of forest products following deforestation as often perceived (e.g. by Bewket 2003; Mekonnen et al. 2007; Duguma and Hager 2010) but also by several other factors that either encourage or discourage planting practices.

The fact that land holding size affects positively and significantly farmers' decision to plant trees while active labour size affects planting decisions negatively and significantly relays an important message that rapid population growth is likely to halt expansion of tree cultivation. This is particularly likely in the study area given the widespread practice of polygamy, the high fertility rate and large family sizes in Arsi Negele district. Though the findings of this study are in line with the common assertion that area of landholding and area of tree plantings are positively related (Biggelaar and Gold 1996; Méndez et al. 2001; Achalu 2004; Abebe 2005; Tolera et al. 2008), the particular relationship between land area allocated to eucalypts and active labour force in the household indicate that such relationships could be negatively affected by population growth.

As area of land holding per household declines, farmers tend to plant more trees per unit area. This practice of dense plantings of eucalypts observed in many of farmers' fields and also as reported by other studies (e.g. Kebebew 2002; Mekonnen et al. 2007) could have been reduced if the amount of land area allocated to tree plantings increased. However, extremely high density stands are ecologically detrimental because high stocking will consume a huge amount of water and soil nutrients and also deter undergrowth as already perceived by the respondent farmers. This is also a further justification for the negative relationship between population growth, high planting stocking and effect of such practices on the environment. It is notable that expansion of eucalypts is taking place despite high awareness among the farmers of the ecologically detrimental effect. Farmers identified several ecological problems associated with eucalypt expansion, including nutrient and space competition with crops and yield reduction, suppression of native plant undergrowth, decline of soil fertility and lowering of water table.

Conclusions

Tree planting is one of the common strategies employed by rural households to diversify income sources, meet their own wood products demands and secure more sustainable livelihoods in Ethiopia. These trees are often considered as financial security for households to cope with unforeseen shocks. The higher financial flow from tree planting due to increasing demand and prices is leading to expansion of eucalypt plantations including conversion of croplands. Expansion has continued

despite the wide perception among the farmers about the ecological detrimental effect of eucalypt species.

Policy-makers and extension program planners in Ethiopia are often concerned with the environmental impacts of eucalypts expansions ignoring farmers' priority to improve their livelihoods. This is undermining the success of many apparently pro-poor rural development projects and programs aimed at enhancing food security. Against all the negatives being said about eucalypts and even the already perceived potential impacts of the species by the farmers themselves, they continue expanding plantings. This suggests that policy-makers and researches need to align themselves along with the farmers in designing systems that sustain the production by generating technologies and management practices for improving productivity and sustainability of small-scale plantations. Measures are needed that facilitate marketing of wood and other tree products, and it might be important to link producers to wood industries to enhance financial gains from their enterprises. Focus should also be on training experts and farmers on environmentally friendly way of managing their eucalypts stands.

It seems also reasonable to conclude that if market incentives exist, in the form of attractive prices and stable markets, and if population growth is managed (since this is shown to negatively affect tree planting) smallholder driven plantation development in Ethiopia could develop with minimal government support. If the environmental concerns of the government and environmentalists is justified the options to slow expansion of eucalypts planting and diversify tree mixes in plantations of farmers is by finding alternative species that fit most of the desirable traits of eucalypts (from biological properties to market demand) and fewer of the undesirable traits. This may not be an easy task in the short term. Thus, rather than attempting to ban the expansion of eucalypt plantations, it might be preferable to explore options to improving site-species matching and management of plantations so as to reduce negative ecological externalities and enhance the positive ecological, economic and social attributes of farm forests.

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